



# **DARPA Robotics Challenge**

## **DRC Trials 2013**

---

### **Initial Task Descriptions (subject to change)**

**Prepared for the DARPA  
DRC team by:**

**National Institute of  
Standards and Technology  
(NIST)**

Adam Jacoff, Raymond Sheh  
Ann Virts, Dave Schmitt

**Southwest Research  
Institute (SwRI)**

Andy Moore, John Quinby

**Golden Knight  
Technologies**

Jim Pippine



## DRC Trials – Initial Task Designs

---

- The following pages are guidelines for teams to develop practice tasks for the DRC Trials (December 2013).
- The actual 8 tasks at the Trials will be similar but in most cases not exactly the same as what is described in this document.
- The DARPA DRC team will solicit feedback from participating teams prior to the DRC Trials.
- The DARPA DRC team will obtain Ranger XP900 vehicles from Polaris with added safety features. Details are in a separate document. Track Teams are not required to use this exact model and configuration in their practice.
- At the DRC Trials, Track Teams may select if they would like the vehicle roll cage installed or removed prior to their run.
- The current plan is to only provide a safety harness to protect the robot from falling on Task 5 (Climb ladder) and possibly Task 2 (Travel Dismounted). Details about how these might be implemented are in the following pages.

# Formative Testing for Teams

## Elemental Tasks for Refinement, Practice, Confidence

### Formative Testing

### DRC Trials – 2013

### DRC Final – 2014

- Teams practice at their own site
- Test apparatuses that are easy to procure and fabricate.
- Provides all necessary practice tasks to succeed at DRC Trials.
- Elemental tests performed individually
- Replicate practice tasks with controlled variability to evaluate capability and robustness
- Several sets of identical setups to enable teams to run simultaneously

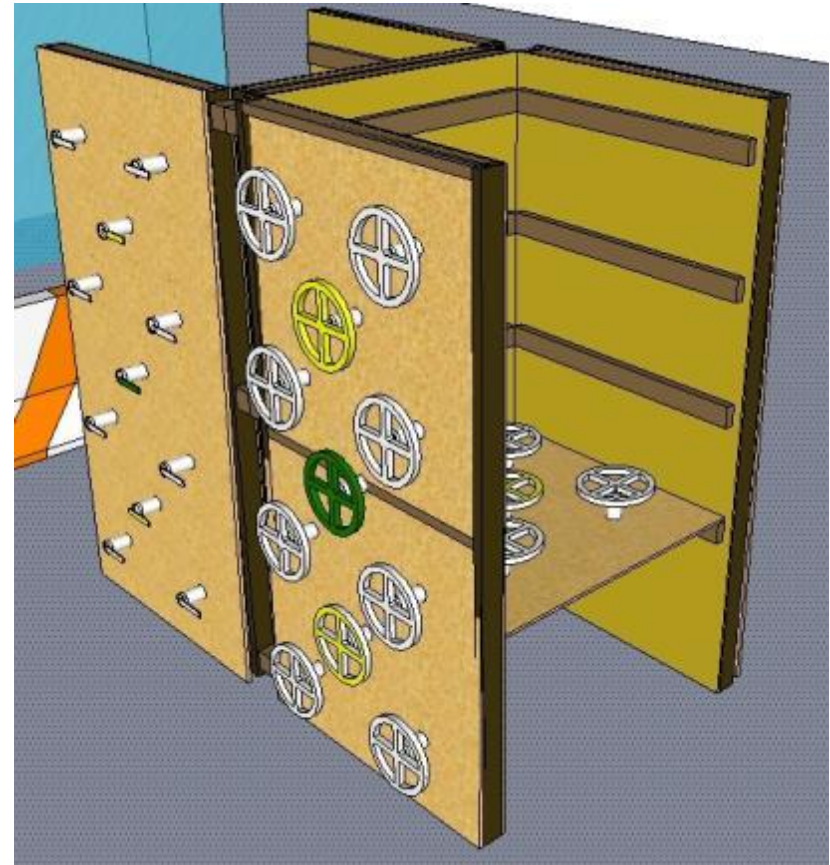
- Operational scenarios with specific measures of performance.
- Tasks will be sequential and integrated.



# Formative Testing for Teams

## Elemental Tasks for Refinement, Practice, Confidence

- Benchmark or standard test methods provide measures of performance over time to track progress within a team, and facilitate comparisons of capabilities across teams anywhere.
- Test method tasks are abstracted from expected operational scenarios to provide specific practice tasks that are repeatable and reproducible with controlled variability.
- Establishing statistical significance (80% reliability with 80% confidence) for any particular task. Less testing inspires less confidence of ultimate success in trials.
- Test apparatuses can also be embedded into operational scenarios to measure performance within degraded environments.
- Track Teams provide feedback to DARPA DRC Team throughout process

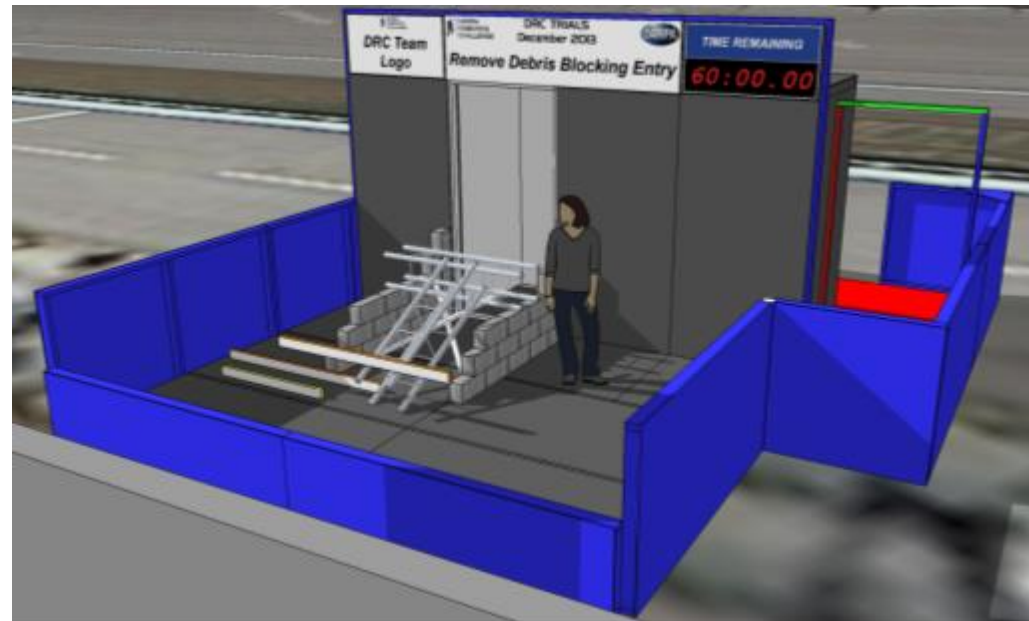


# DRC Trials

## "Task Stage" Fabrication



A "Task Stage" concept assembled using connected "Task Walls" and blank walls. Entire assembly can ship to DRC Trials in one pallet.



Optional 1.2 m (4 ft) tall perimeter walls (blue) could enhance overall safety by separating active robots from administrators, team members, press, etc. Start gate shown uses colors based on virtual challenge.



# Robotic Challenge Trials Tasks



## Capability Exercised

Autonomy - Perception	Autonomy – Decision-making	Mounted Mobility	Dismounted Mobility	Dexterity	Strength	Endurance
X	X	X		X		
X			X			X
X			X	X	X	X
X			X	X		X
X			X			X
X	X			X	X	X
X	X		X	X	X	X
X			X	X	X	X

## Sample Tasks

1. Drive utility vehicle	X	X	X		X		
2. Travel dismounted through various terrains	X			X			X
3. Remove debris blocking entryway	X			X	X	X	X
4. Open doors, enter building	X			X	X		X
5. Climb ship's ladder/stairs	X			X			X
6. Break through wall	X	X			X	X	X
7. Locate and close valve	X	X		X	X	X	X
8. Connect firehose	X			X	X	X	X



Elemental Task 1

---

# **Drive Utility Vehicle**

# Task 1: Drive Utility Vehicle

## Polaris Ranger XP900

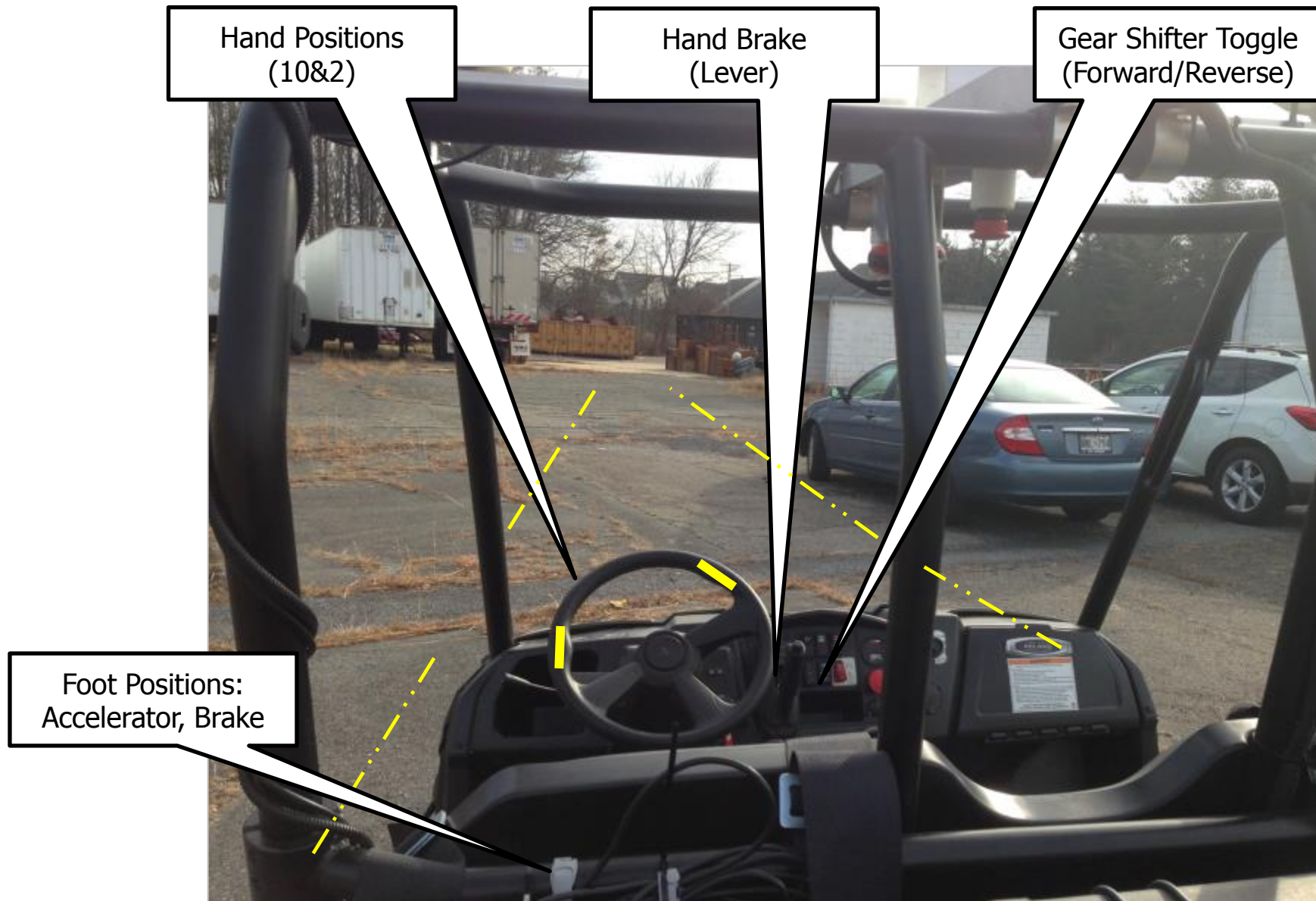
- The vehicle has a drive by wire throttle (speed control), a "valet key" to limit top speed to 10mph, and a remote E-Stop.
- 450 kg (1000lb) capacity in the payload bed to carry generator for Atlas robot.
- Polaris roll bar surrounding cab (officially the Roll Over Protection System or ROPS) is bolted onto frame for quick removal.
- Tilting steering wheel is provided for more leg clearance.
- Bench seat allows the robot to sit in the middle of the vehicle while driving.
- Turf mode or 2WD will be used during trials.





# Task 1: Drive Utility Vehicle

## Vehicle Safety Check and Touch Points

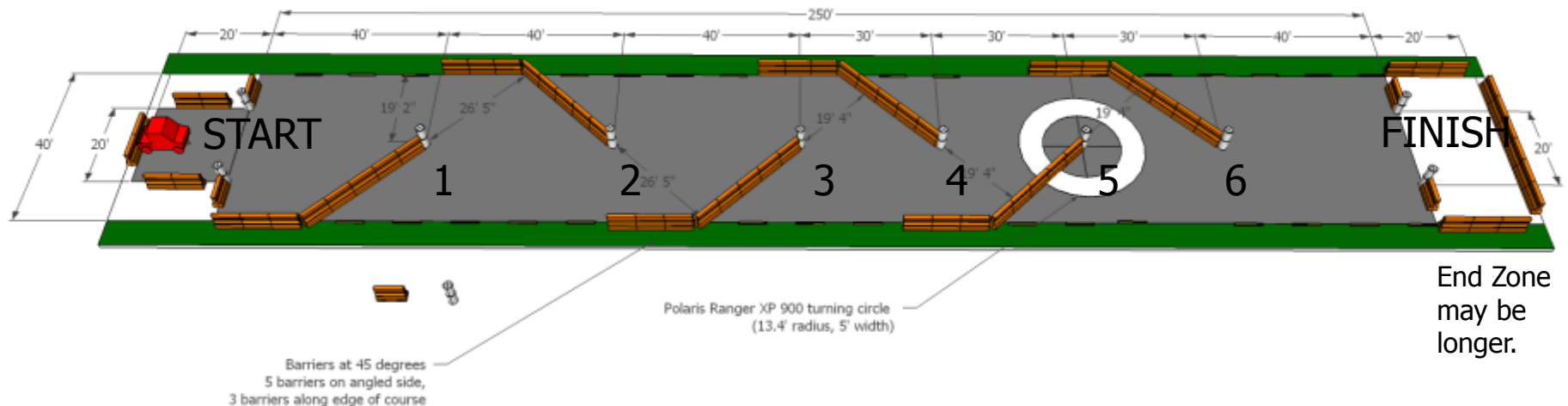


# Task 1: Drive Utility Vehicle

## Course Layout

### Dimension Details:

- 250 ft long overall
- 40 ft wide (limited by proposed roadway)
- 40 ft between start line and pylons 1-2-3
- 30 ft between pylons 3-4-5-6-
- Obstacles include double tall barrel pylons with continuous barriers at 45 degree angle to side boundaries
- Vehicle turning radius is shown in white



# Task 1: Drive Utility Vehicle

## Course Components



1.8 m (6 ft) tall double barrel pylons (blue) and barriers (alternating orange/white) define essentially a slalom course.



Parking guides provide sideline markers over which the vehicle is not allowed to cross.



# Task 1: Drive Utility Vehicle

## Course Layout Tips



Place measuring tape down centerline of intended course.



Use SPRAY CHALK (NOT PAINT) and the inside of a tape role to mark solid circles at pylon spacings.



Vehicle barriers ends have joint recesses that are ideal for clear positioning. Center of barrel pylons is also easy.



Elemental Task 2

---

## **Travel Dismounted**



## Task 2: Travel Dismounted

### Increasingly Complex Terrain

Straight forward path of increasingly challenging terrains that are easy to source and fabricate and enable easy tether management (tether may be suspended from a zip-line which could also be used to belay the robot during practice and early trials)

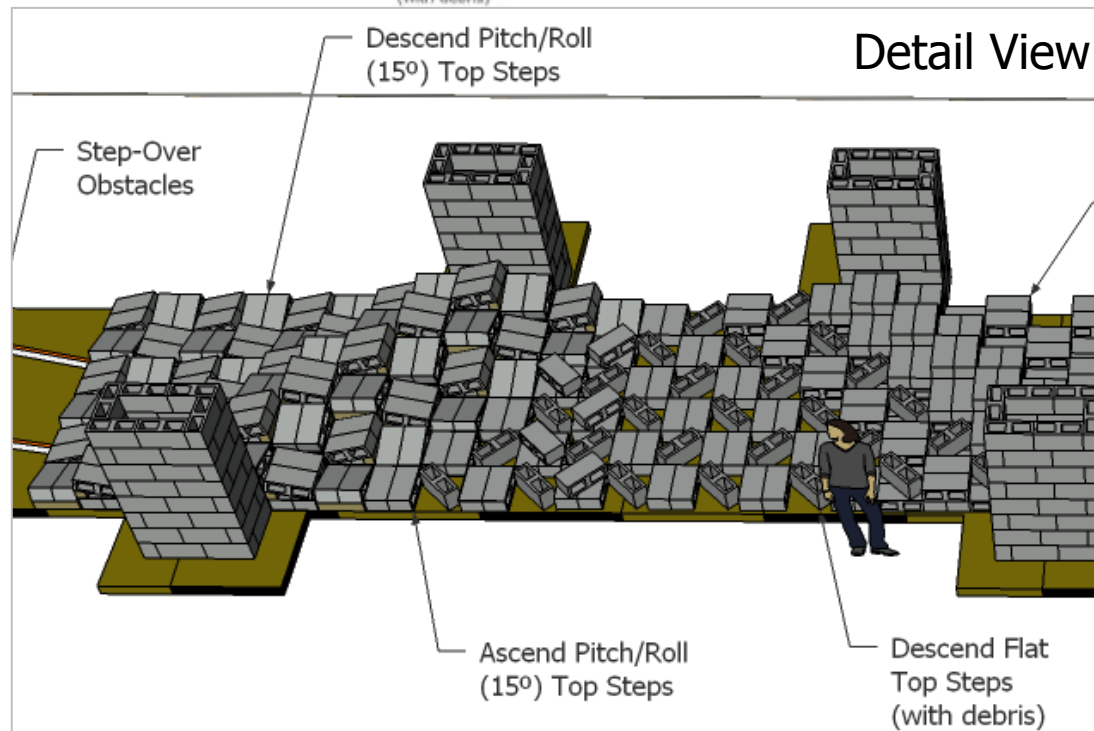
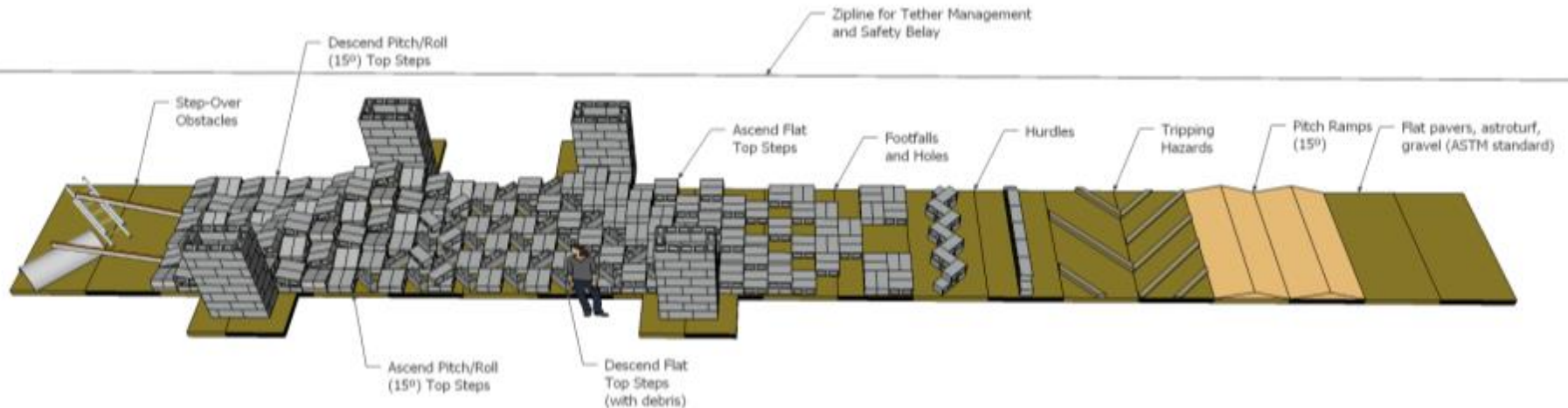
- 2.1 Flat pavers and Astroturf
- 2.2 Pitch Ramps (15°) (ASTM Standard)
- 2.3 Tripping Hazards
- 2.4 Hurdles
- 2.5 Footfalls and Holes
- 2.6 Ascend Flat Top Steps
- 2.7 Descend Flat Top Steps
- 2.8 Ascend Pitch/Roll (15°) Top Steps
- 2.9 Descend Pitch/Roll (15°) Top Steps
- 2.10 Step-Over Obstacles



Each sub terrain is 8 ft square x 10 increasingly difficult terrains = 80 ft long.

# Task 2: Travel Dismounted

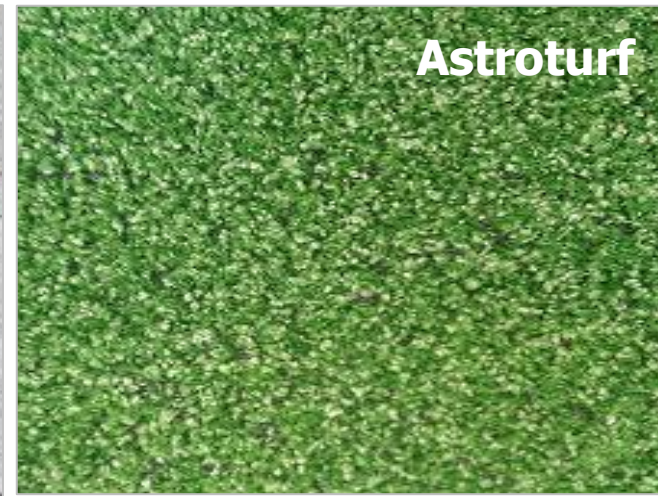
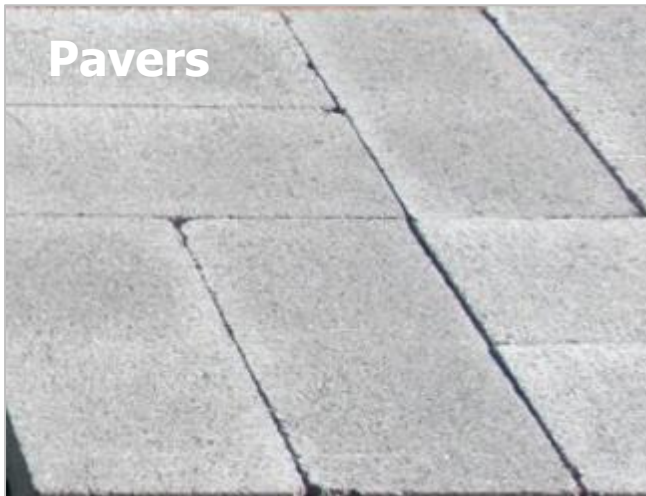
## Increasingly Complex Terrain



## Task 2.1: Travel Dismounted

### Flat: Pavers and Astroturf

Each sub terrain is 2.4 m (8 ft) square. There are 10 increasingly difficult terrains.  
So the overall task is 24 m (80 ft) long.





## Task 2.2: Travel Dismounted Pitch/Roll Ramps (15°)

Each sub terrain is 2.4 m (8 ft) square. There are 10 increasingly difficult terrains.  
So the overall task is 24 m (80 ft) long.



## Task 2.3: Travel Dismounted

### Tripping Hazards: Diagonal 2x4s and 4x4s

Each sub terrain is 2.4 m (8 ft) square. There are 10 increasingly difficult terrains.  
So the overall task is 24 m (80 ft) long.





## Task 2.4: Travel Dismounted

### Block Hurdles: 15 cm (6 in) and 30 cm (12 in)

Each sub terrain is 2.4 m (8 ft) square. There are 10 increasingly difficult terrains.  
So the overall task is 24 m (80 ft) long.



## Task 2.5: Travel Dismounted

Footfalls/Holes: 80 cm (32 in) and 40 cm (16 in) squares

Each sub terrain is 2.4 m (8 ft) square. There are 10 increasingly difficult terrains.  
So the overall task is 24 m (80 ft) long.





## Task 2.6: Travel Dismounted Ascend Diagonal Hill Stepfield

Each sub terrain is 2.4 m (8 ft) square. There are 10 increasingly difficult terrains.  
So the overall task is 24 m (80 ft) long.



## Task 2.7: Travel Dismounted Descend Diagonal Hill Stepfield

Each sub terrain is 2.4 m (8 ft) square. There are 10 increasingly difficult terrains.  
So the overall task is 24 m (80 ft) long.





## Task 2.8: Travel Dismounted

### Ascend Diagonal Hill Stepfield with Pitch/Roll Tops

Each sub terrain is 2.4 m (8 ft) square. There are 10 increasingly difficult terrains.  
So the overall task is 24 m (80 ft) long.





## Task 2.9: Travel Dismounted

### Descend Diagonal Hill Stepfields with Pitch/Roll Tops

Each sub terrain is 2.4 m (8 ft) square. There are 10 increasingly difficult terrains.  
So the overall task is 24 m (80 ft) long.

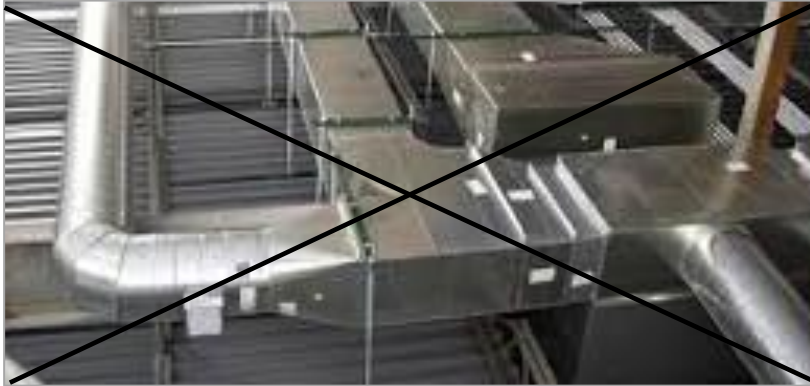


## Task 2.10: Travel Dismounted

### Step-Over Obstacles: < 30 cm (12 in)

Each sub terrain is 2.4 m (8 ft) square. There are 10 increasingly difficult terrains.  
So the overall task is 24 m (80 ft) long.

No Crushable Items



Screwed Down to Subfloor



No Compressible Items



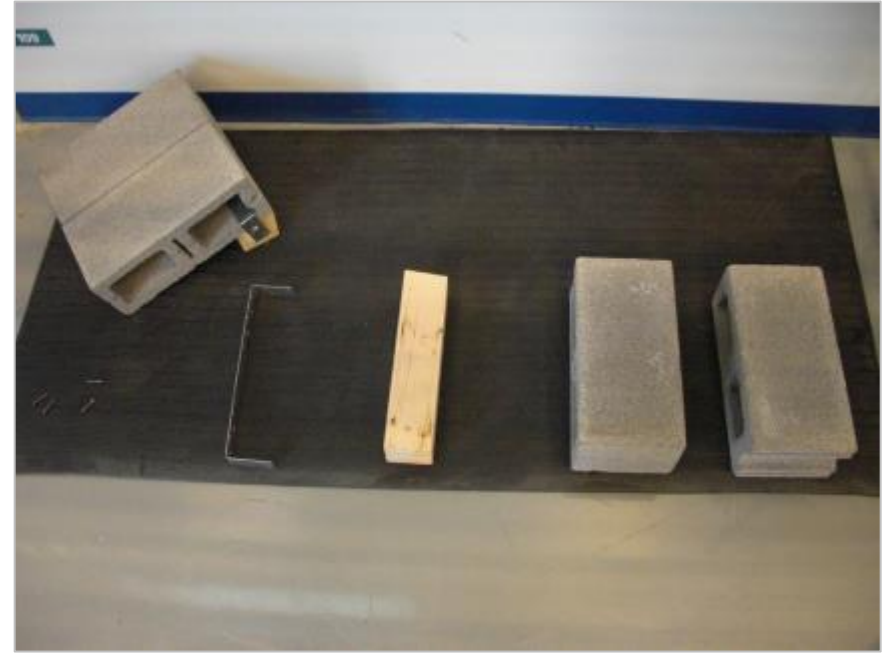
No Rolling/Moving Objects like Pipes

## Task 2: Travel Dismounted

### Fabrication of Stepfield with Pitch/Roll Tops



Two side-by-side cinder blocks are held together on a 15° incline using a 4x4 (3.5" x 3.5") 10 x 10 cm post cut to angle and a steel strip bent appropriately and screwed into the sides of the post.

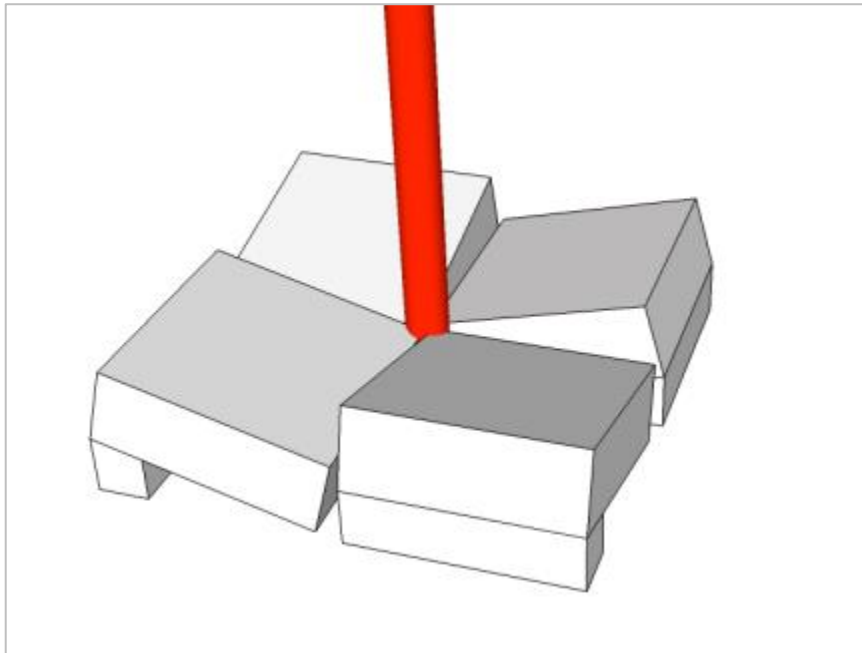


All the components are shown, including 4 screws. The 4x4 posts should be cut to sit flatly on the floor with a 15° angle on the top face

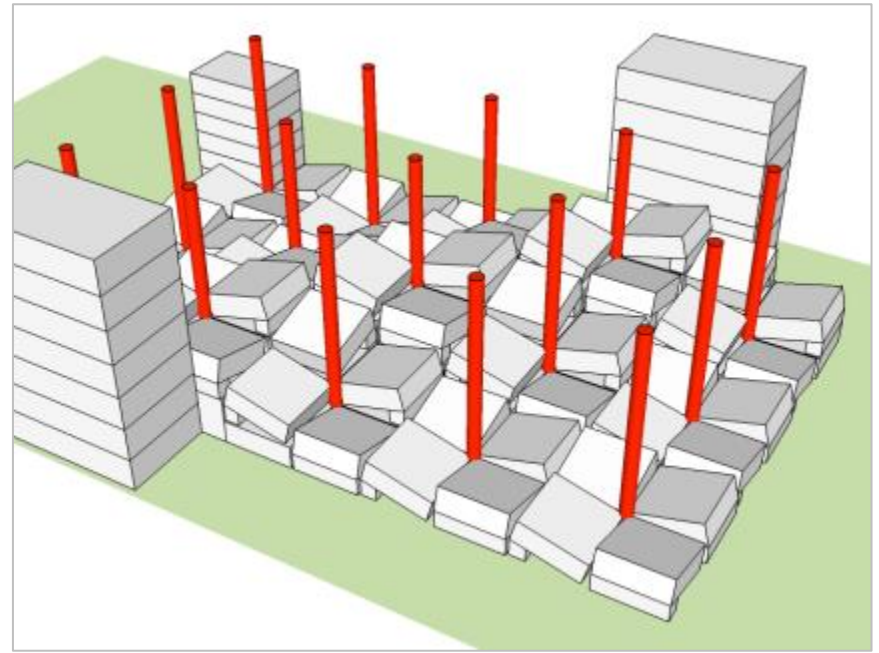


## Task 2: Travel Dismounted

### Fabrication of Stepfield with Pitch/Roll Tops



The Pitch/Roll Top Steps are assembled to form a "pin wheel" design on top of the increasing/decreasing elevation of blocks forming a diagonal ridge across the terrain.



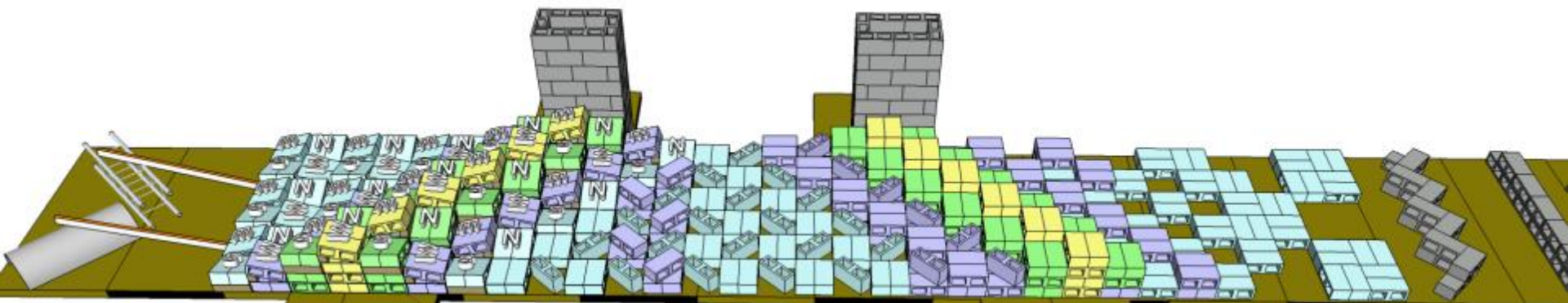
The red rods are only for visualization purposes to locate the centers of the "pin wheel" designs. Note that given the incline/decline of the underlying stacks of blocks, the "pin wheel" blocks will never all be all at the same elevation.

# Task 2: Travel Dismounted

## Assembly of Stepfield with Pitch/Roll Tops



Top View

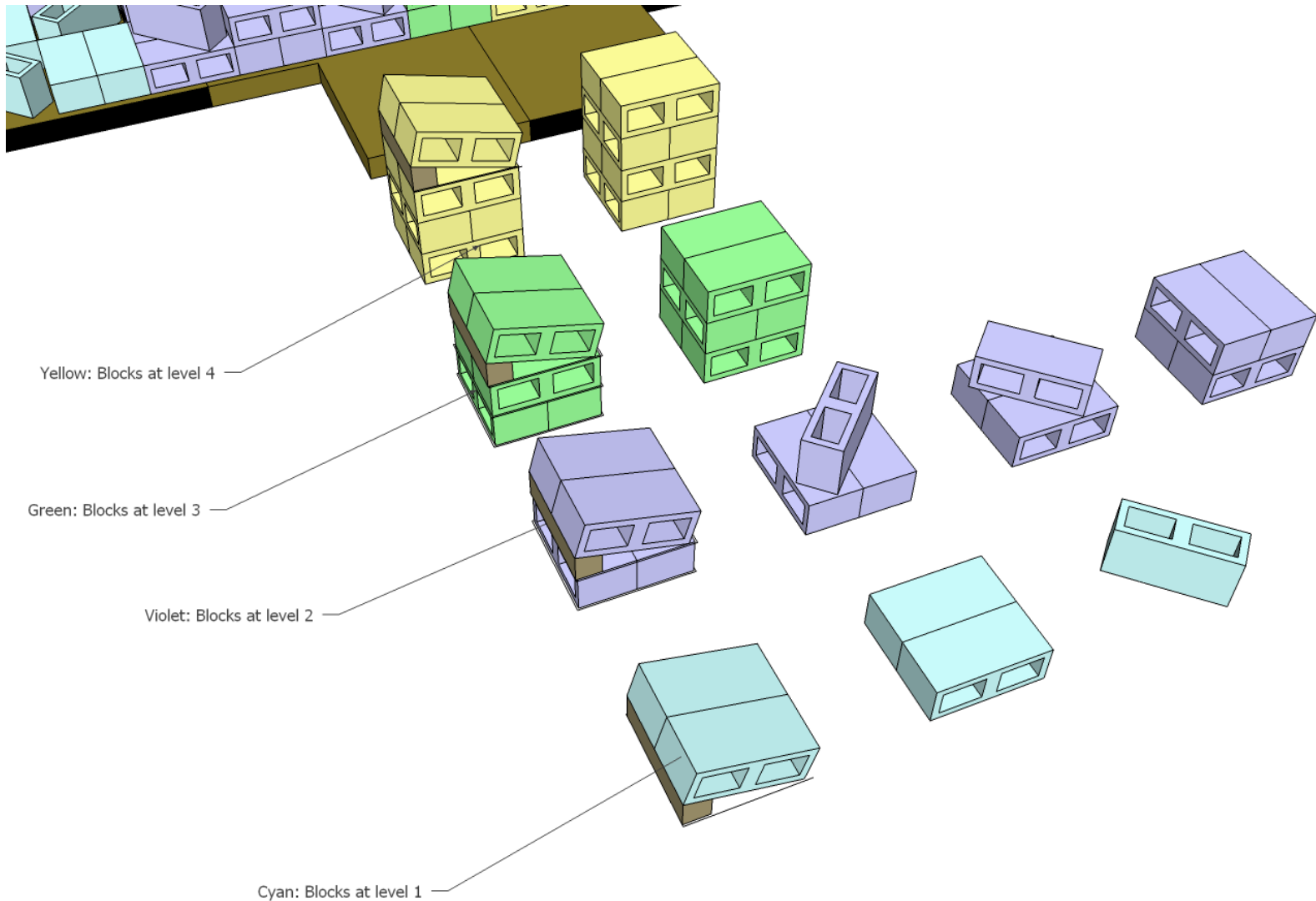


Perspective View



## Task 2: Travel Dismounted

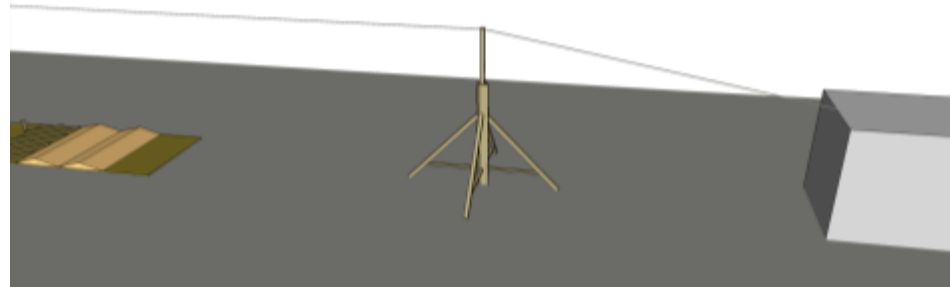
### Assembly of Stepfield with Pitch/Roll Tops



## Task 2: Travel Dismounted

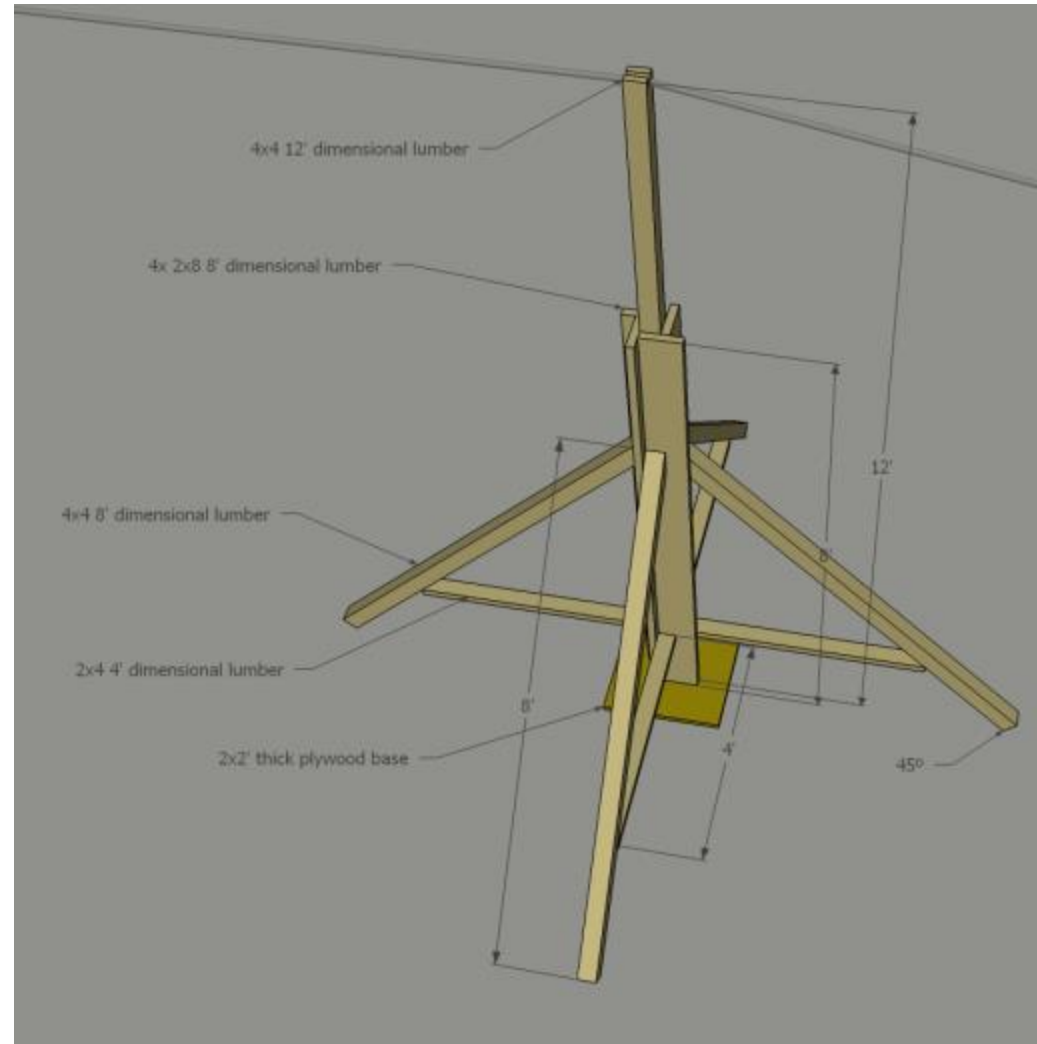
### Zip-line Tether Belay and Potential Robot Belay

- Fabricated 3.6 m (12 ft) tall posts provide the elevation needed for 2.1 m (7 ft) tall robots on hill terrain.
- 6 m (20 ft) or 12 m (40 ft) ISO container can be used as anchors about 20 m (60 ft) from ends of terrain.
- Nylon straps 5 cm (2 in) x 80 cm (32 in) wrap through corner ISO connectors to hook cable and 4,500 kg (10,000 lb) ratcheting winch.
- 1 cm (3/8 in) diameter galvanized aircraft cable 7x19 construction and 4,500 kg (10,000 lb) strength.
- Self-retracting lifeline belay mechanism used by construction workers provides passive belay.
- This is the initial concept for Belay for the DRC Trials. This setup will be future developed and details released in the coming months.



## Task 2: Travel Dismounted

### Zip-line Tether Belay and Potential Robot Belay







Elemental Task 3

---

## **Remove Debris Blocking Entry**

## Task 3: Remove Debris Blocking Entry

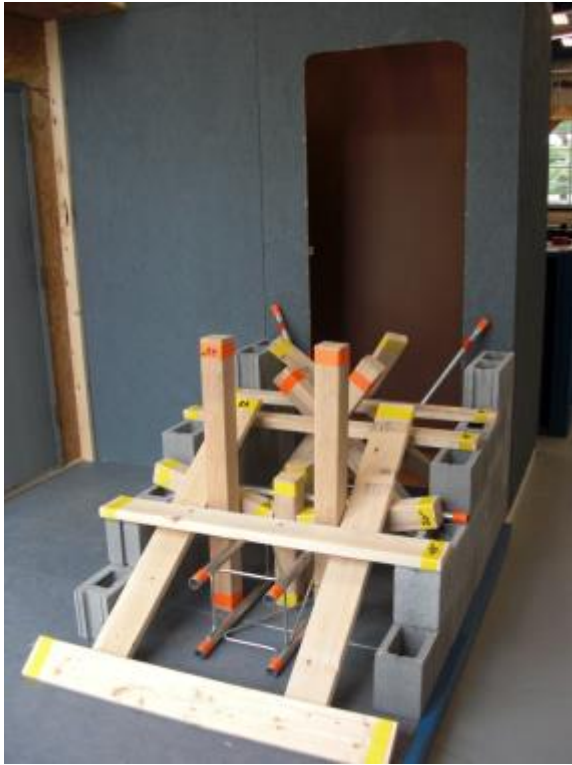
### 2.2 kg (5 lb) and 4.4 kg (10 lb) Debris



The stage shown (grey) is 4.8 m (16 ft) wide x 3.6 m (12 ft) deep x 3.0 m (10 ft) tall with a central alcove for the robot to enter that is 80 cm (32 in) wide x 2.1 m (7 ft) tall blocked with well defined debris in a describable arrangement. The entry has partial cinder block walls on both sides to contain the debris and ensure all robots approach the pile similarly. This task encourages grasping, lifting, and placing enough debris over the side of the partial walls to pass through the entry.

## Task 3: Remove Debris Blocking Entry

### 2.2 kg (5 lb) and 4.4 kg (10 lb) Debris



A self standing Task Wall can be fabricated by teams or assembled into the DRC Trial Stage (with additional signage header over top and optional terrain in front)



# Task 3: Remove Debris Blocking Entry

## 2.2 kg (5 lb) and 4.4 kg (10 lb) Debris

Items with ORANGE marking  
weigh less than 4.4 kg (10 lb).

Items with YELLOW marking  
weigh less than 2.2 kg (5 lb).



Alum. Truss  
30x30x150 cm  
(12x12x60 in)

3 Pipes  
3.7D x 120 cm  
(1.5D x 48 in)

4 Long Posts  
"4 x 4"  
10x10x100 cm  
(3.5x3.5x40 in)

4 Wide Boards  
"2 x 6"  
5x15x120 cm  
(1.5x5.5x48 in)

4 Boards  
"2 x 4"  
5x10x120 cm  
(1.5x3.5x48 in)

4 Short Posts  
"4 x 4"  
10x10x50 cm  
(3.5x3.5x20 in)



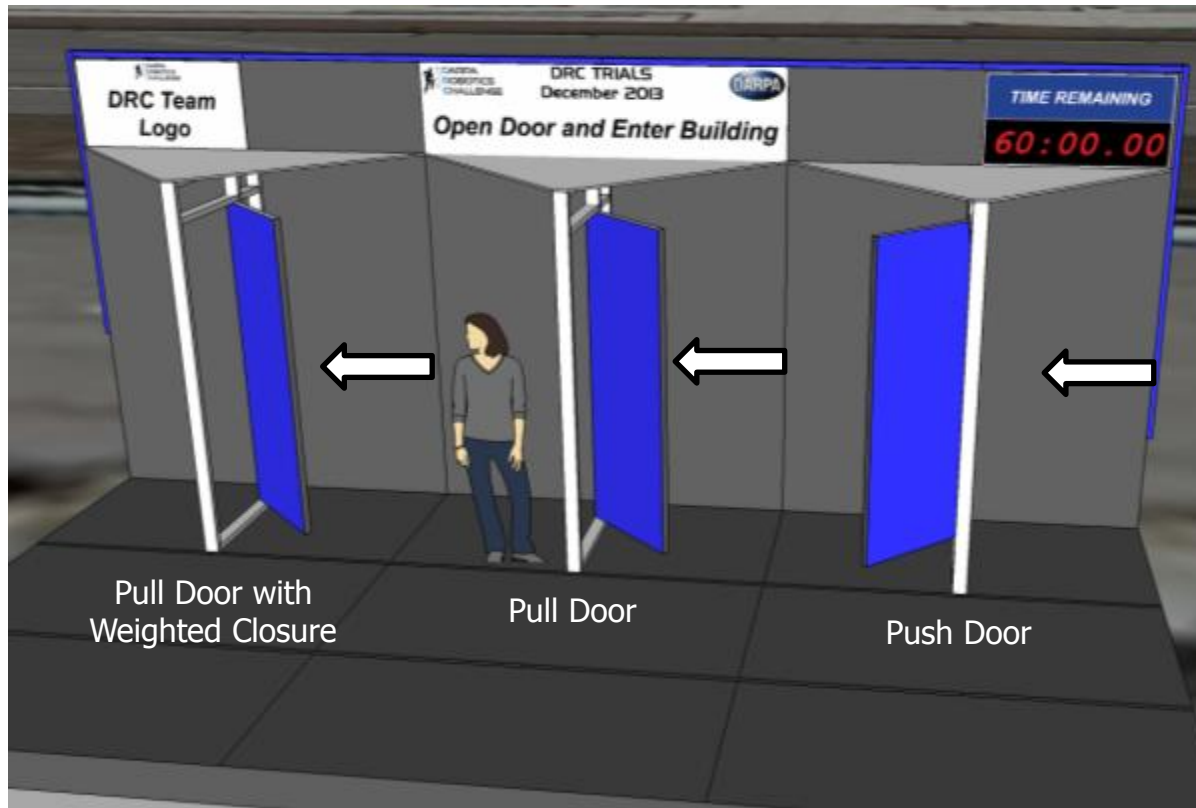
Elemental Task 4

---

## **Open Door and Enter Building**

## Task 4: Open Door, Enter Building

### Push, Pull, and Weighted Closure Doors



The stage shown (grey) is 7.2 m (24 ft) wide x 3.6 m (12 ft) deep x 3.0 m (10 ft) tall with three metal doors 80 cm (32 in) wide. The progression of doors shown is from right to left through a push door, then a pull door, then a pull door with weighted closure. All doors have lever handles.

A single door can be fabricated on a double "Task Wall" as a practice apparatus to perform push, pull, and pull with weighted closure tasks.





Elemental Task 5

---

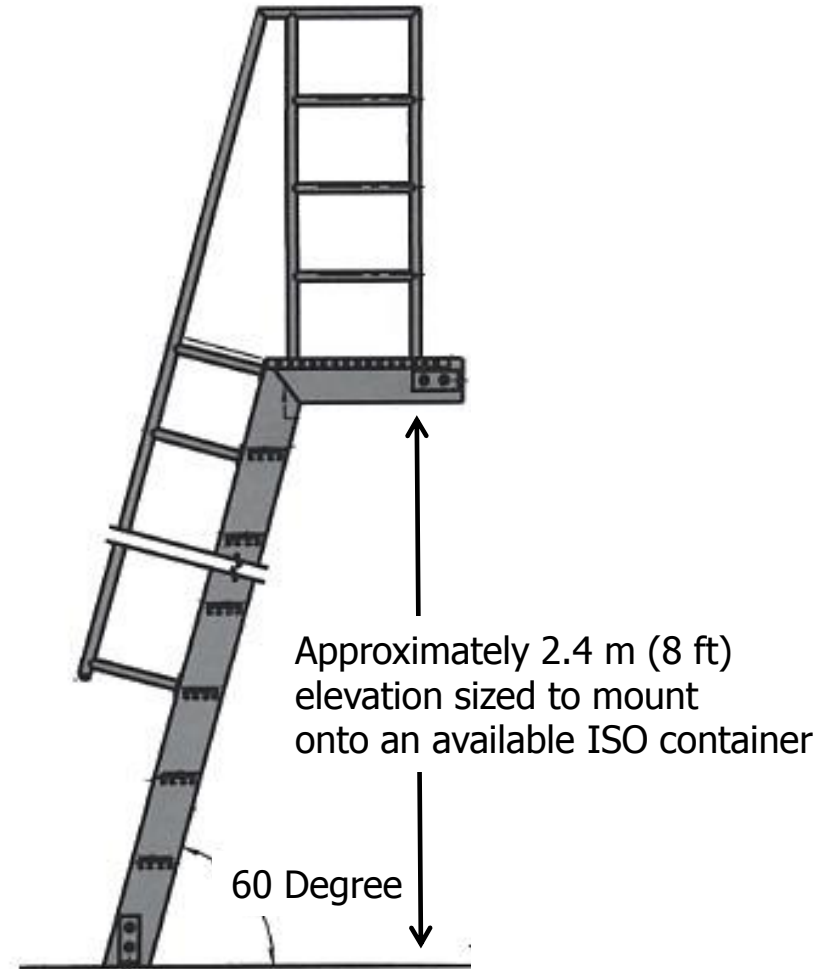
## **Climb Industrial Ladder**

## Task 5: Climb Industrial Ladder

60 Degree Incline, 80 cm (32 in) wide



Stairs inside Fukushima-Daiichi plant occluded and impassible by conventional robots.



80 cm (32 in) width between railings

## Task 5: Climb Industrial Ladder

### 60 Degree Incline, 80 cm (32 in) wide

The 60 degree inclined stair shown is about 80 cm (32 in) wide with a 60 cm (2 ft) landing at the top.

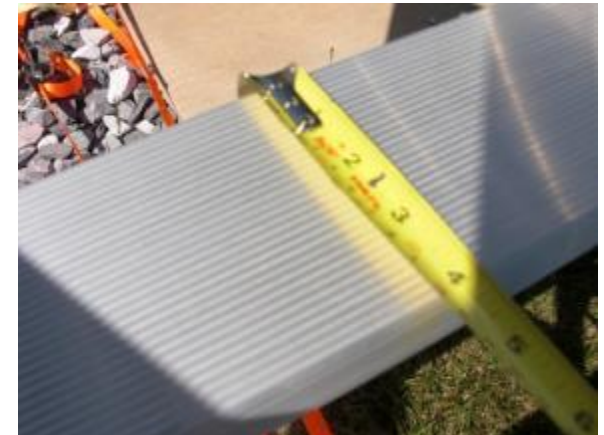
The window-washing platform abutting it is not part of this elemental task.

A wood base under the bottom feet and upper landing enable strapping to the ISO container.



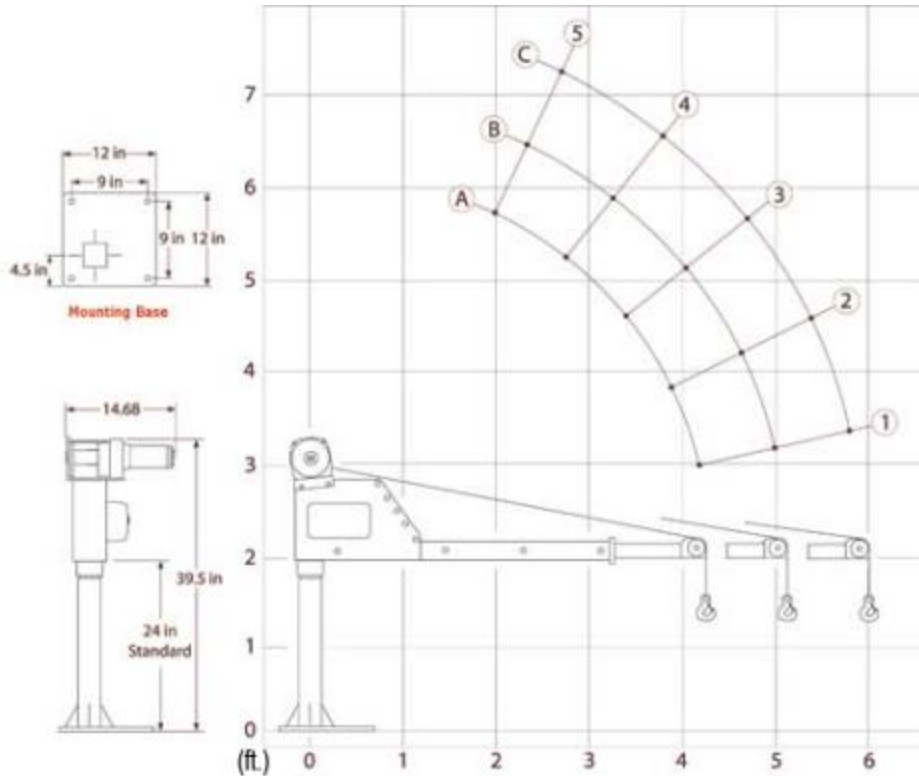
Step Height: 30 cm (12 in)

Step Depth: 10 cm (4 in)



# Task 5: Climb Industrial Ladder

## 60 Degree Incline, 80 cm (32 in) wide



A JIB CRANE, or DAVITT CRANE, typically attached to trucks, docks, or boats (e.g. to move jet skis) inserts into the top of an appropriately sized vertical pipe. The crane has a motorized hoist that is faster than the robot can climb and a tethered pendant to enable safe belaying of the robot from an appropriate distance.



An ISO CONTAINER provides a secure counter weight with mounting locations in the corners for two HORIZONTAL ISO CONNECTORS mounted to the top and bottom corner nearest to the stairs.



# Task 5: Climb Industrial Ladder

## Safety Belay for Robots

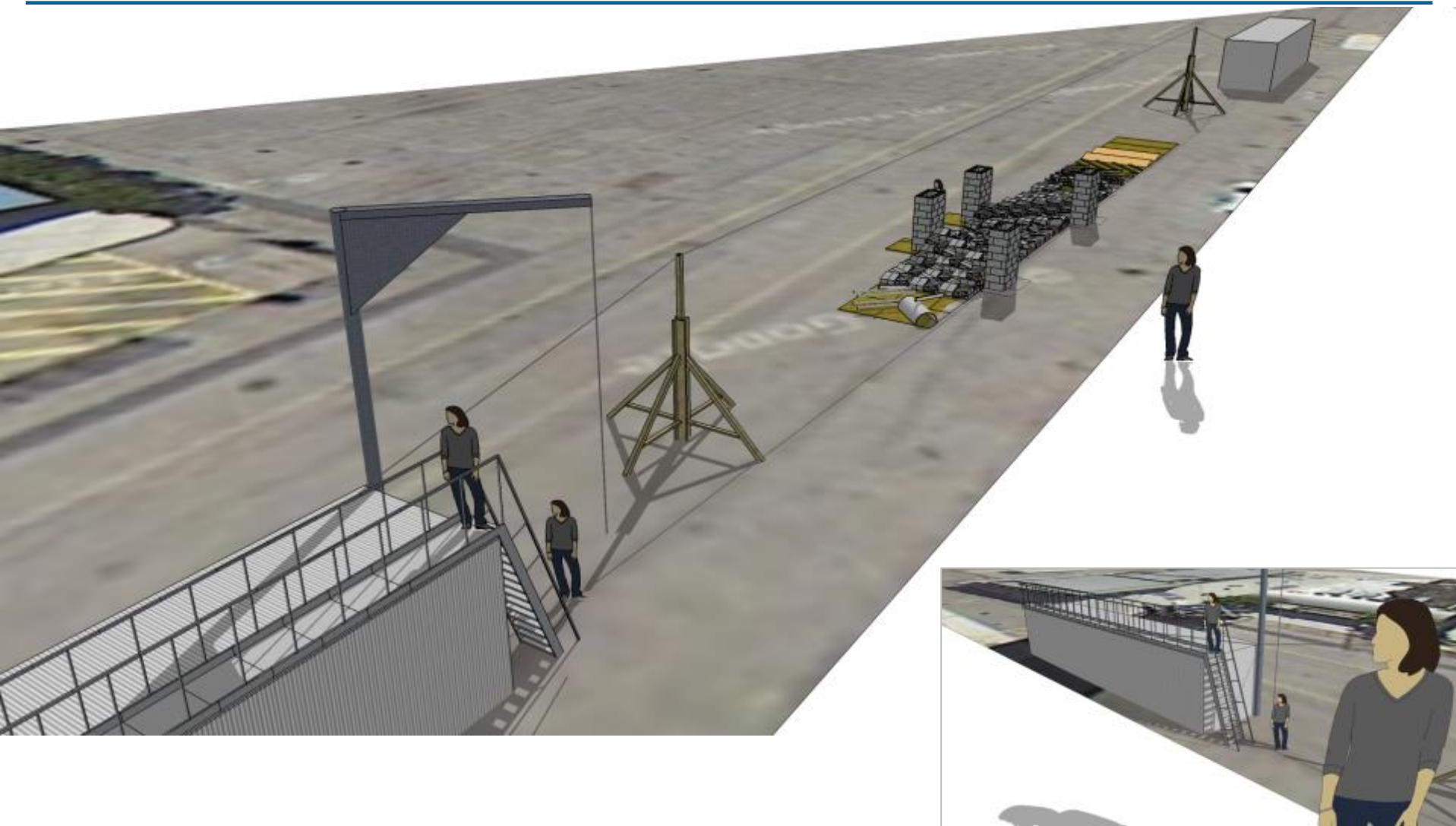
### FALL ARREST DEVICE or SELF- RETRACTING LIFELINE



A FALL ARREST DEVICE, or SELF-RETRACTING LIFELINE, typically used by construction workers provides a passive belay mechanism hooked to the motorized jib hook over the base of the stairs. The team's safety officer need only keep the jib crane's hook height above the robot's head. **Any latching of the belay system should be considered the end of trial.**

## Task 5: Climb Industrial Ladder

### Leveraging ISO Containers Used for Terrain Belay





Elemental Task 6

---

# **Break Through Wall**

# Task 6: Break Through Wall

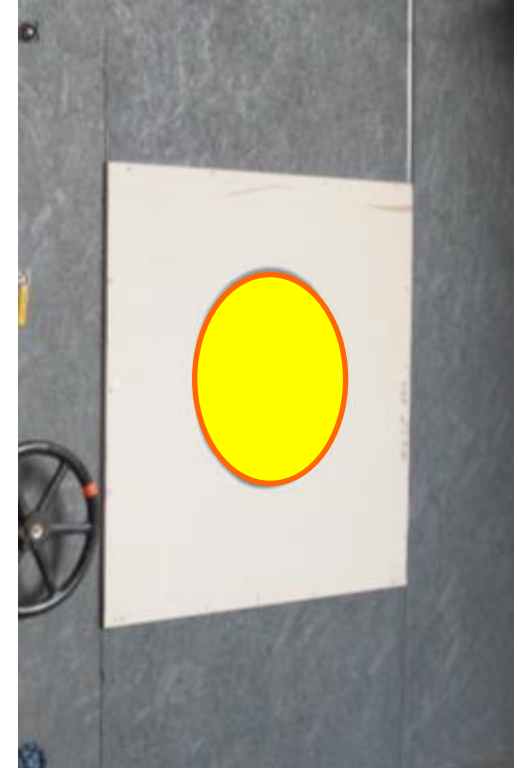
## Task Wall Apparatus



A self standing Task Wall can be fabricated by teams or assembled into the DRC Trial Stage (with additional signage header over top and optional terrain in front)



The back side of the Task Wall has lumber supports placed horizontally centered at 60 cm (2 ft) and 90 cm (6 ft) elevation to attach replaceable 1.2 m (4 ft) square panels of dry wall or hardi-board for cutting.



A target can be placed on the Task Wall as an indicator of the area intended to be removed. It should be roughly a 60 cm (2 ft) geometric shape.



## Task 6: Break Through Wall

### Cutting Tools

- Three different tools and two different wall surfaces (drywall and hardi-board) could be used.
- Tools will weigh less than 5 kg
- It is planned that all tools will be cordless and powered by battery



Rotary Tool  
(i.e. Dewalt 18V Cordless Cut-Out Tool)



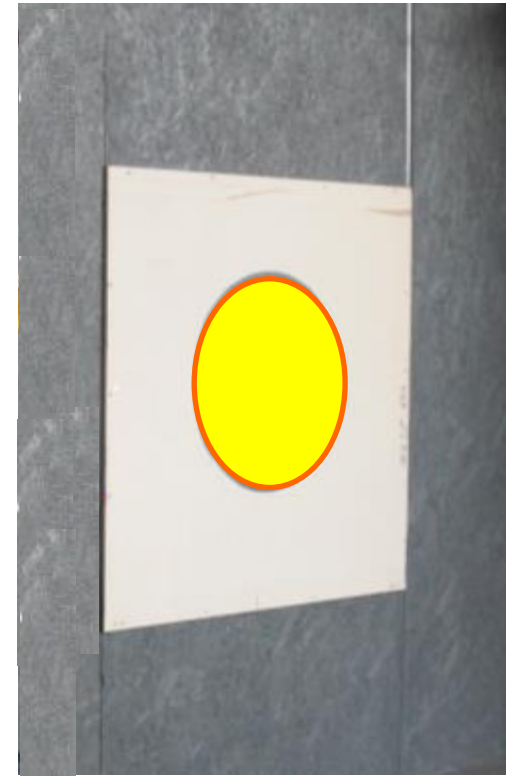
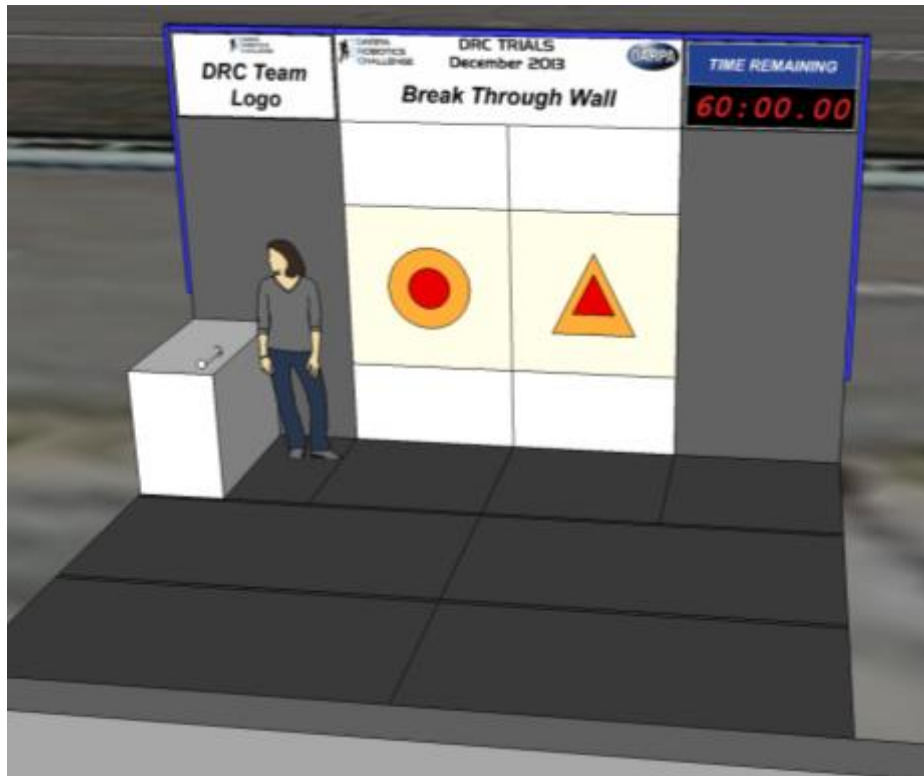
Multi-Tool with Trigger  
(i.e. Ryobi P340 18V Cordless Job Pil)



Two Handle Drill and Bit Saw  
(i.e. Skil 2895 18V Cordless Drill)

# Task 6: Break Through Wall

## Proposed Stage for DRC Trials





Elemental Task 7

---

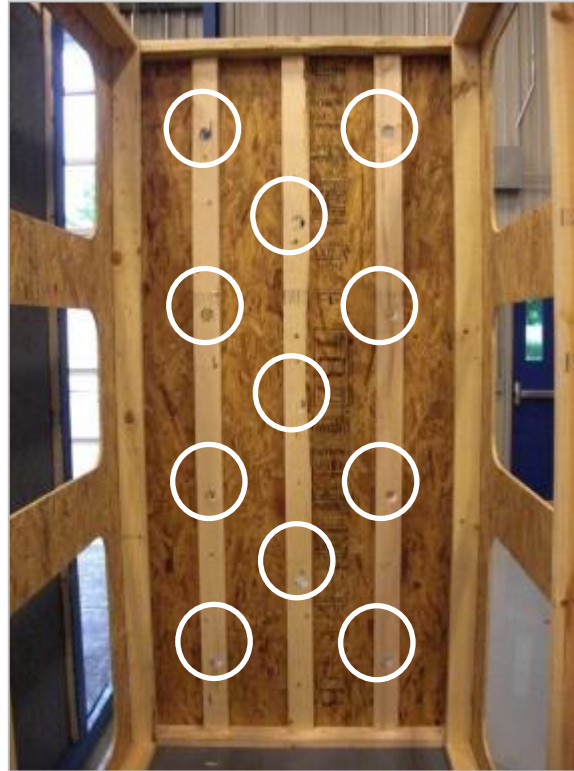
## **Locate and Close Valves**

# Task 7: Locate and Close Valves

## Task Wall Apparatus – Vertical



A self standing Task Wall can be fabricated by teams or assembled into the DRC Trial Stage (with additional signage header over top and optional terrain in front)



Back side of the Task Wall has stud supports placed vertically with holes at task locations to attach fabricated valve assemblies.

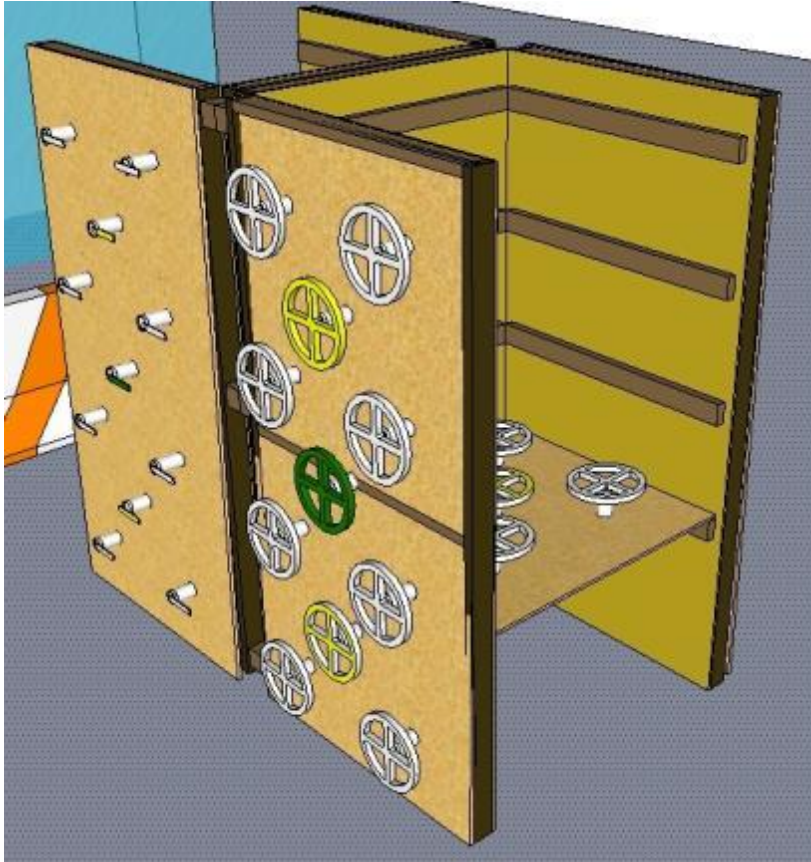


The front Task Wall Unit is populated with valve assemblies in a typical 5-dice pattern.



# Task 7: Locate and Close Valves

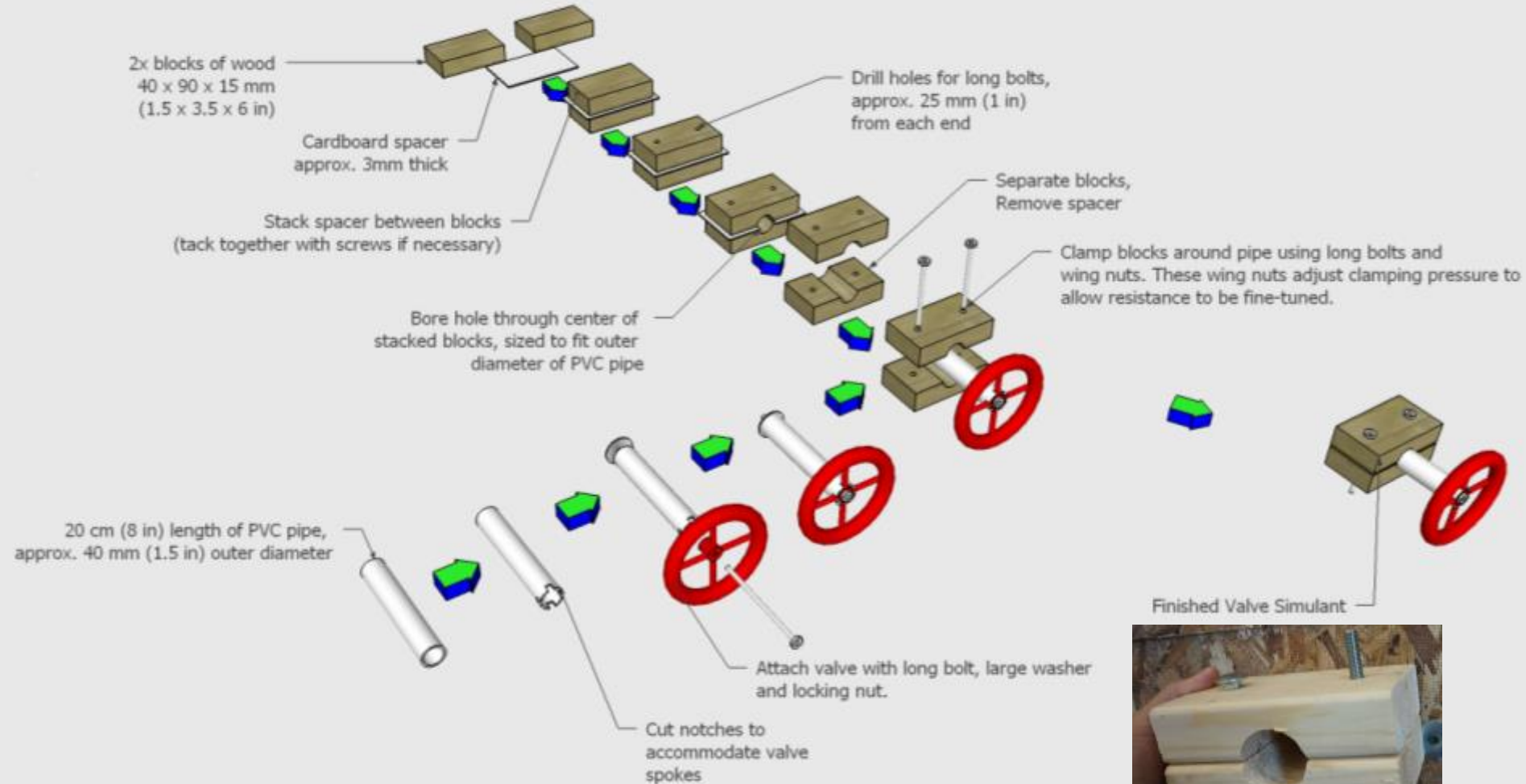
## Task Wall Apparatus - Horizontal



The back side of the self standing Task Wall has an adjustable shelf at 30, 60 90, 120 cm (1, 2, 3, 4 ft) elevations. with 5-dice pattern of the valves. All positions can be populated with the same handwheel type/size, or a variety can be used.

# Task 7: Locate and Close Valves

## Simple Variable Torque Assembly



# Task 7: Locate and Close Valves

## Proposed Stage for DRC Trials





Elemental Task 8

---

## **Carry, Unspool, and Connect Fire Hose**

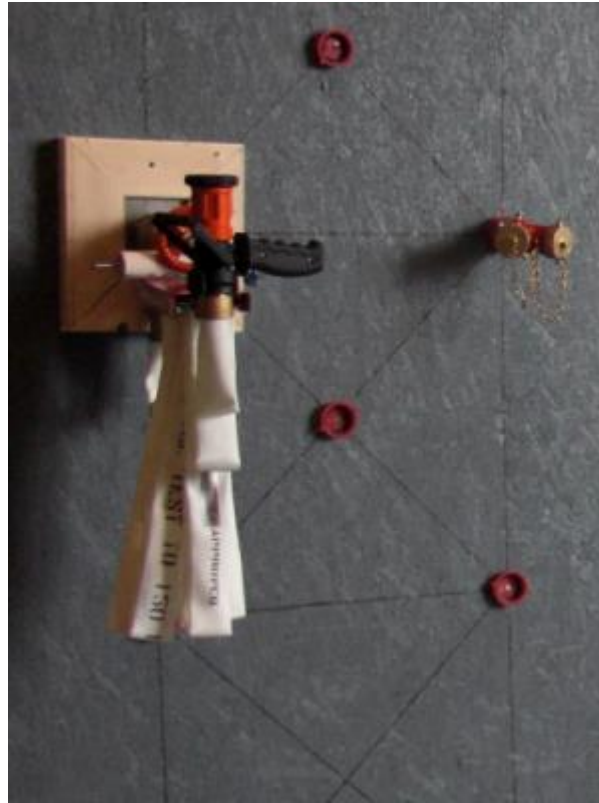


# Task 8: Carry, Unspool, and Connect Fire Hose

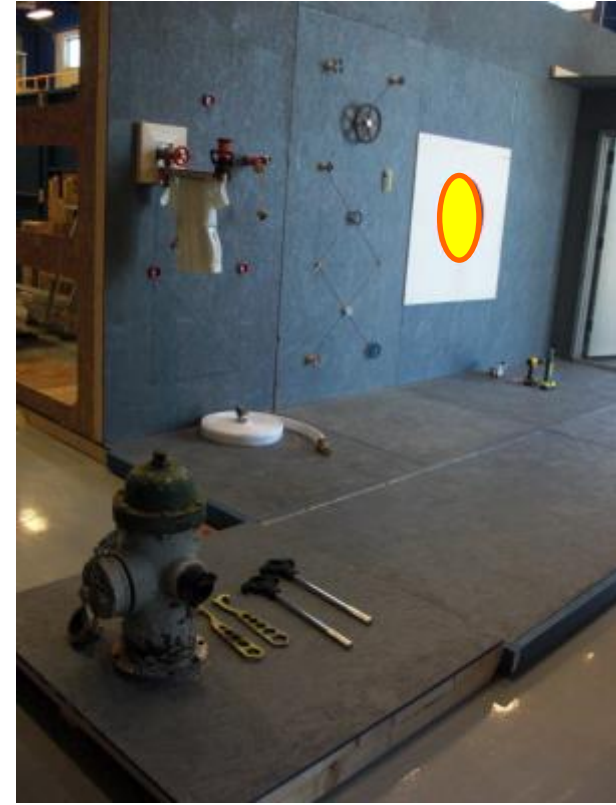
## Task Apparatus



A self standing Task Wall can be fabricated by teams or assembled into the DRC Trial Stage (with additional signage header over top and optional terrain in front)



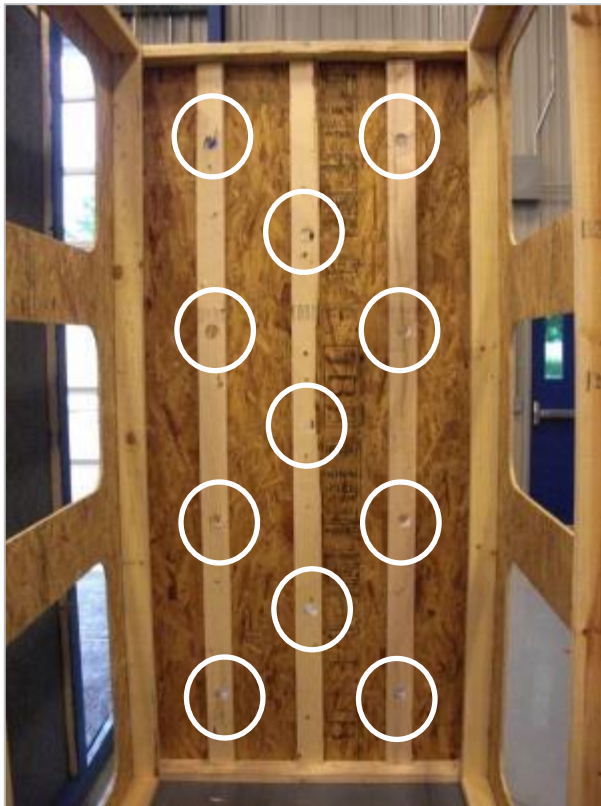
Fire hose reel, OS&Y valve, and caps can be placed anywhere on the wall in the 5-dice locations to support a variety of task options.



A fire hydrant can be attached to a pallet and placed some distance away from the Task Wall for final connection of the fire hose.

# Task 8: Carry, Unspool, and Connect Fire Hose

## Task Apparatus



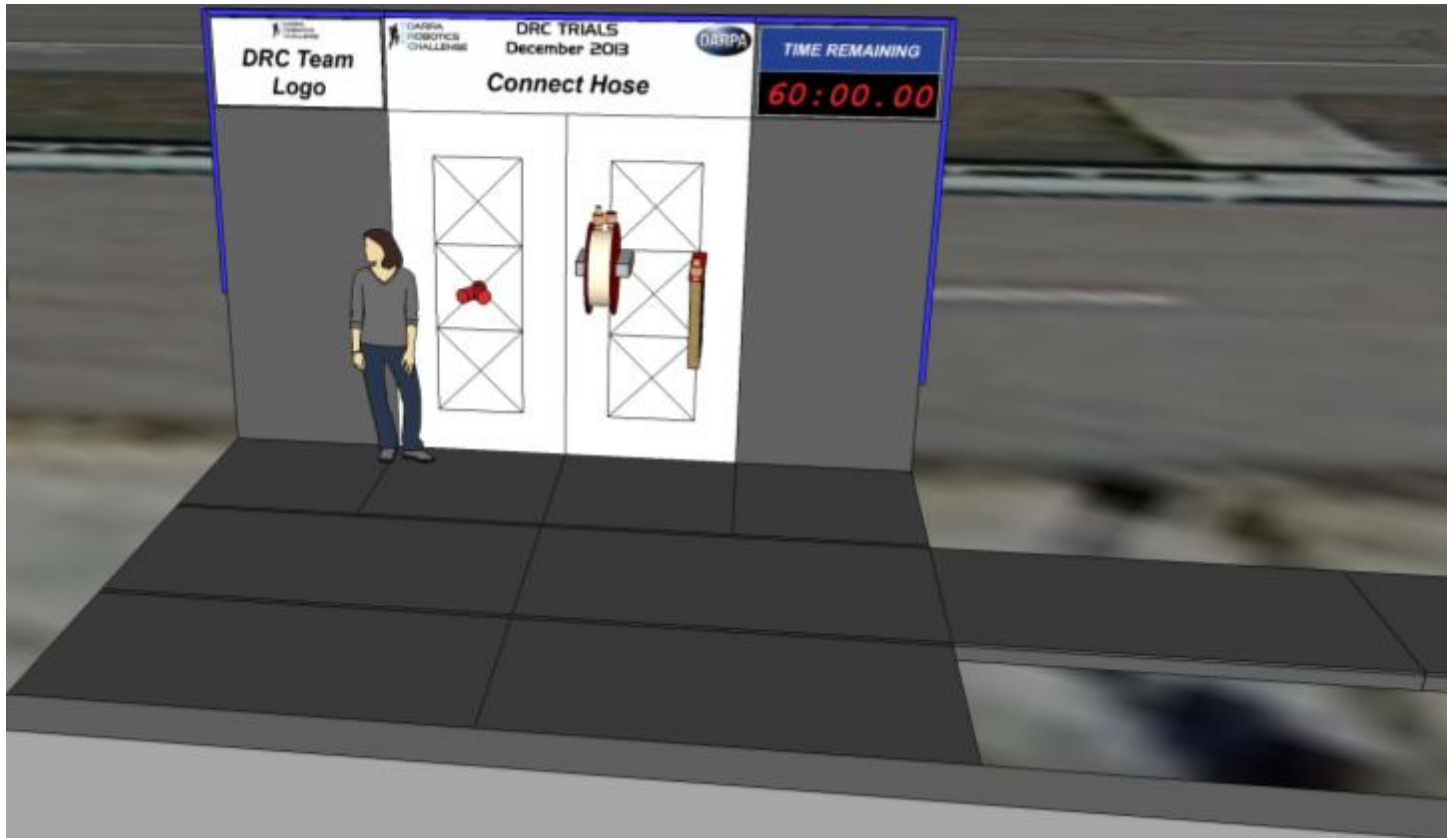
Behind the Task Wall lumber supports placed vertically provide secure mounting for hose reel, OS&Y valve and caps.



Examples of fire hose reels and OS&Y valves.

# Task 8: Carry, Unspool, and Connect Fire Hose

## Task Options



## Task 8: Carry, Unspool, and Connect Fire Hose

### Task Options

